

WHAT IS CLAIMED IS:

1     1.    An     apparatus     for     thermal     sterilization of a  
2           microbiologically     contaminated     liquid     to     produce a  
3           thermally treated liquid, said apparatus comprising:

4                 a pressure vessel enclosing a pressure space therein  
5           and having a vessel inlet and a vessel outlet;

6                 a heater arranged in a heating zone in said pressure  
7           space within said pressure vessel; and

8                 a heat exchanger arranged in said pressure vessel,  
9           having a heat exchanger inlet, a heat exchanger outlet and  
10          a heat exchange wall defining first and second flow paths  
11          along opposite sides of said heat exchange wall;

12                wherein at least one of said heat exchanger inlet and  
13          outlet is connected to at least one of said vessel inlet  
14          and outlet respectively, so that the contaminated liquid  
15          can flow into said pressure vessel through said vessel  
16          inlet, along said first flow path in a first net flow  
17          direction, and through said heating zone to from the  
18          treated liquid, and the treated liquid can flow from said  
19          heating zone along said second flow path in a second net  
20          flow direction and out of said pressure vessel through said  
21          vessel outlet, while heat is transferred from the treated  
22          liquid to the contaminated liquid through said heat  
23          exchange wall.

1     2.    The apparatus according to claim 1, wherein said heat  
2           exchanger is a counterflow heat exchanger, and the second

net flow direction is opposite the first net flow direction.

3. The apparatus according to claim 2, wherein said heat exchanger is configured, dimensioned, arranged and adapted so that a substantial proportion of energy needed for heating the contaminated liquid is retained inside said pressure vessel by re-cooling of the treated liquid along said second flow path of said heat exchanger before the treated liquid exits said pressure vessel.

4. The apparatus according to claim 1, wherein only one of said heat exchanger inlet and outlet is connected to only one of said vessel inlet and outlet respectively at a distal end of said heat exchanger relative to said heating zone, and another of said heat exchanger inlet and outlet is open within said pressure space in said pressure vessel at a proximal end of said heat exchanger relative to said heating zone.

5. The apparatus according to claim 1, wherein said heat exchanger outlet is connected to said vessel outlet at a distal end of said heat exchanger relative to said heating zone, and said heat exchanger inlet is open within said pressure space in said pressure vessel at a proximal end of said heat exchanger relative to said heating zone.

1     **6.**    The apparatus according to claim 1, wherein said second  
2            flow path is bounded and enclosed by said heat exchange  
3            wall and thereby confined inside said heat exchanger, and  
4            said first flow path is a portion of said pressure space  
5            surrounding said heat exchanger within said pressure  
6            vessel.

1     **7.**    The apparatus according to claim 1, wherein said heat  
2            exchanger has a hollow pipe-shape, and said heat exchange  
3            wall is a cylindrical pipe wall enclosing said second flow  
4            path therein.

1     **8.**    The apparatus according to claim 1, wherein said heater is  
2            an electric resistance heater, and further comprising a  
3            temperature sensor arranged in said heating zone within  
4            said pressure vessel, and a power regulator connected to  
5            said temperature sensor to receive a temperature signal  
6            therefrom and connected to said electric resistance heater  
7            to apply thereto electrical power regulated dependent on  
8            the temperature signal.

1     **9.**    The apparatus according to claim 1, further comprising a  
2            pressurizing pump outside of said pressure vessel connected  
3            to said vessel inlet.

1     **10.**   The apparatus according to claim 9, further comprising a  
2            pressure-reducing device outside of said pressure vessel  
3            connected to said vessel outlet.

- 1     **11.** The apparatus according to claim 10, wherein said  
2         pressure-reducing device is connected for energy  
3         transmission to said pressurizing pump.
- 1     **12.** The apparatus according to claim 11, comprising a common  
2         shaft or a mechanical transmission by which said  
3         pressure-reducing device is connected to said pressurizing  
4         pump.
- 1     **13.** The apparatus according to claim 11, wherein said  
2         pressurizing pump and said pressure-reducing device  
3         together form a pressurizing-depressurizing module.
- 1     **14.** The apparatus according to claim 11, further comprising a  
2         drive motor connected to said pressurizing pump.
- 1     **15.** The apparatus according to claim 9, further comprising an  
2         excess pressure relief device connected to said vessel  
3         inlet parallel to said pressurizing pump.
- 1     **16.** The apparatus according to claim 1, further comprising a  
2         pressure-reducing turbine outside of said pressure vessel  
3         connected to said vessel outlet.
- 1     **17.** An apparatus for thermal sterilization of a  
2         microbiologically contaminated liquid, said apparatus  
3         comprising:

4 a pressure vessel enclosing a pressure space therein  
5 and having a vessel inlet and a vessel outlet;

6 a heater arranged in a heating zone in said pressure  
7 space within said pressure vessel;

8 a counterflow heat exchanger arranged in said pressure  
9 vessel, having a proximal end and a distal end relative to  
10 said heating zone, said proximal end being open to said  
11 pressure space within said pressure vessel, and said distal  
12 end being connected for flow communication with said vessel  
13 inlet or said vessel outlet; and

14 a pressurizing pump outside of said pressure vessel  
15 connected to said vessel inlet.

1 **18.** The apparatus according to claim 17, further comprising a  
2 pressure-reducing device outside of said pressure vessel  
3 connected for flow communication with said vessel outlet,  
4 and connected mechanically for power transmission to said  
5 pressurizing pump.

1 **19.** A method for thermally sterilizing a microbiologically  
2 contaminated liquid to produce a thermally treated liquid,  
3 comprising the steps:

- 4 a) pressurizing said contaminated liquid;  
5 b) flowing said contaminated liquid in a first flow  
6 direction along a first side of a heat exchanger  
7 thereby pre-heating said contaminated liquid with heat  
8 transferred from said heat exchanger;

- 9 c) flowing said contaminated liquid through a heating  
10 zone, and in said heating zone, heating said  
11 contaminated liquid with a heater to a sufficiently  
12 high treatment temperature for achieving the thermal  
13 sterilization of said contaminated liquid to produce  
14 said treated liquid;
- 15 d) flowing said treated liquid in a second flow direction  
16 opposite said first flow direction along a second side  
17 of said heat exchanger physically separated from and  
18 in thermal communication with said contaminated liquid  
19 on said first side of said heat exchanger, thereby  
20 cooling said treated liquid by transferring heat from  
21 said treated liquid to said heat exchanger; and  
22 e) reducing a pressure of said treated liquid.

1 **20.** The method according to claim 19, wherein said step e)  
2 further comprises recovering energy from said reducing of  
3 said pressure, and then further comprising using said  
4 energy in performing said step a).

1 **21.** The method according to claim 19, wherein said treatment  
2 temperature in said step c) is above a normal atmospheric  
3 boiling point of said contaminated liquid, and said  
4 contaminated liquid is maintained in a liquid state because  
5 said contaminated liquid is pressurized to above  
6 atmospheric pressure in said step a).

1     **22.** The method according to claim 19, wherein said contaminated  
2       liquid is pressurized to a pressure of at least 16 bar in  
3       said step a) and said pressure is maintained in said steps  
4       b), c) and d), and wherein said treatment temperature in  
5       said step c) is at least 200°C.